Marine Pollution Bulletin 160 (2020) 111650

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Baseline

Low level of microplastic contamination in wild fish from an urban estuary

Lang Lin[a], Li-Sha Ma[b], Heng-Xiang Li[a,g,*], Yun-Feng Pan[a,f], Shan Liu[a,g], Li Zhang[c], Jin-Ping Peng[d], Lincoln Fok[e], Xiang-Rong Xu[a,g], Wei-Hong He[c]

[a] Key Laboratory of Tropical Marine Bio-Resources and Ecology, Guangdong Provincial Key Laboratory of Applied Marine Biology, South China Sea Institute of Oceanology, Innovation Academy of South China Sea Ecology and Environmental Engineering, Chinese Academy of Sciences, Guangzhou 510301, China
[b] Pearl River Fisheries Research Institute, Chinese Academy of Fishery Sciences, Guangzhou 510380, China
[c] Marine Environmental Testing Center, South China Sea Institute of Oceanology, Innovation Academy of South China Sea Ecology and Environmental Engineering, Chinese Academy of Sciences, Guangzhou 510301, China
[d] Faculty of Chemical Engineering and Light Industry, Guangdong University of Technology, Guangzhou 510006, China
[e] Department of Science and Environmental Studies, The Education University of Hong Kong, Hong Kong Special Administrative Region, China
[f] University of Chinese Academy of Sciences, Beijing 100049, China
[g] Southern Marine Science and Engineering Guangdong Laboratory (Guangzhou), Guangzhou 511458, China

ARTICLE INFO

Keywords:
Microplastic
Fish
Ingestion
Gill
Fiber

ABSTRACT

Microplastic accumulation in estuarine environments is considered the dominant input of land-based plastics into the oceans. In this study, the level of microplastic contamination was evaluated in 26 species of wild fish from the Pearl River Estuary, South China. Results showed that microplastics abundance ranged from 0.17 items individual^{-1} (*Boleophthalmus pectinirostris* & *Acanthogobius flavimanus*) to 1.33 items individual^{-1} (*Plectorhynchus cinctus*) among different species. The distribution of microplastic abundance in the gills and gastrointestinal tracts was not significantly different. Microplastics in gills are strongly related to the filtration area of gills in 15 fish species. Fibers were the dominant shapes accounting for 93.45% of the total shapes. The majority of microplastics were < 3 mm in size. The most common polymer composition was polyethylene terephthalate (38.2%) and the most common color was black (30.36%). The findings of this study provide baseline data for microplastic contamination in wild fish from an urban estuary.

Global plastic production continues to grow, with an increase of 43% over the last decade (PlasticEurope, 2016). It has been reported that approximately 4.8 to 12.7 million tons of plastic waste was discharged by 192 coastal countries into the ocean (Jambeck et al., 2015). These plastic debris gradually fragment into microplastics (< 5 mm) under the processes of weathering, degradation due to ultraviolet radiation, and tidal and biological interactions (Peters and Bratton, 2016), which tend to have potential negative effects on aquatic organisms (Diepens and Koelmans, 2018). Ingestion of microplastics has been reported for a variety of aquatic organisms, including zooplankton (Desforges et al., 2015), bivalves (Van Cauwenberghe et al., 2015), fish (Alomar et al., 2017), turtles (Vélez-Rubio et al., 2018) and mammals (Nelms et al., 2018). Once ingested, microplastics are likely to result in mechanical damage (Bellas et al., 2016; Jabeen et al., 2018; Lei et al., 2018) and negative effects such as reduced feeding, fecundity, decreased growth and survival chances (Cole et al., 2016). Recently, fish as food sources for humans have aroused extensive attention due to the risks of bioaccumulation of microplastics and potential biomagnification of plastic-associated contaminants in fish (Santillo et al., 2017). Microplastics have been extensively detected in the gastrointestinal tracts (GIT) of fish in marine environments (Baalkhuyur et al., 2018; Bessa et al., 2018; Pozo et al., 2019). The prevalence of microplastics in fish of predator species has shown that microplastics may also be ingested indirectly as a result of trophic transfer, whereby contaminated prey items are consumed (Farrell and Nelson, 2013). Previous studies on fish mainly focused on microplastic contamination in digestive systems (Abbasi et al., 2018). However, the digestive tracts are not the only way that toxins enter the bodies of fish. A vital respiratory organ of many aquatic organisms, the gill is frequently ignored despite its considerable microplastic accumulation ability. In some fish, such as Clupeiformes, the gill also serves the feeding function (Elsheikh, 2013). Filter-feeding fish possess numerous and elongate rakers on the back side of the gill arch, which can be used as a net to extract food from the water flow and subsequently direct food toward the esophagus (Gibson, 1988). As a result, the gills are likely to massively accumulate the environmental microplastics, to which close

* Corresponding author.
E-mail address: hxli@scsio.ac.cn (H.-X. Li).

https://doi.org/10.1016/j.marpolbul.2020.111650
Received 2 June 2020; Received in revised form 4 September 2020; Accepted 5 September 2020
Available online 10 September 2020
0025-326X/

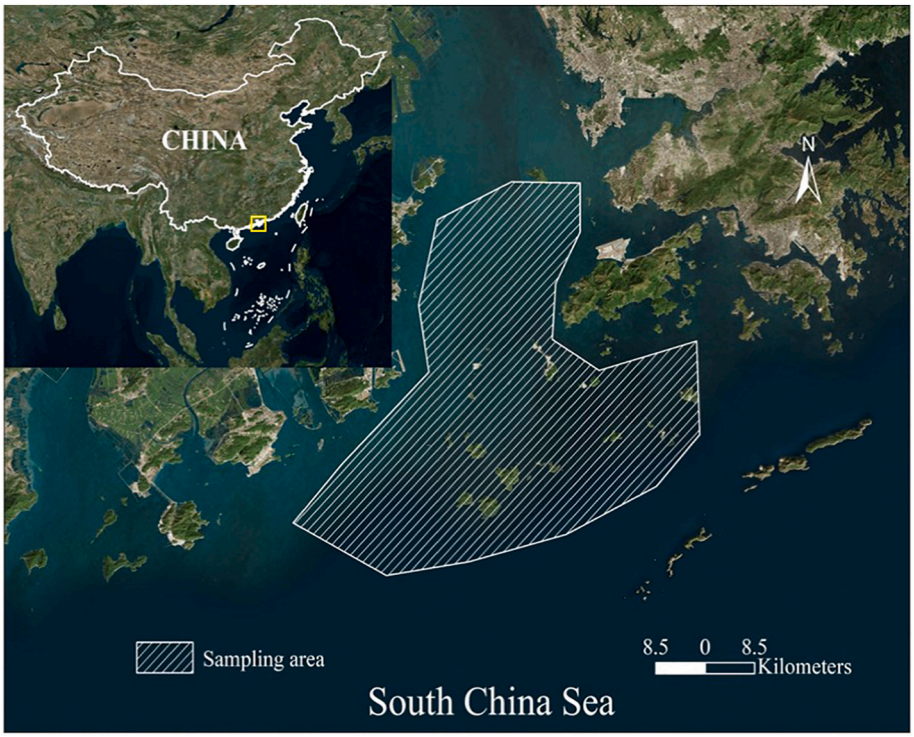

Fig. 1. Sampling area in the Pearl River Estuary.

attention should be paid.

The Pearl River Estuary (PRE) is the largest estuary in South China. In recent years, high abundance of microplastics has been widely detected in surface water, sediments, and beaches in the Pearl River and its estuarine environments (Mai et al., 2019; Yan et al., 2019; Zheng et al., 2019; Zuo et al., 2020). Ubiquitous microplastics in the PRE may affect the aquatic organisms living there; however, little information is known about the contamination of microplastics in biotas from the estuary. Therefore, this study investigated the occurrence and distribution of microplastics in wild fish collected from the PRE and potential sources of microplastic ingestion were examined, with the aim of assessing the environmental risk of microplastic contaminants in important estuarine areas and developing related ecological protection strategies.

A total of 337 fish of 26 species were captured by a fishing boat in the relevant sampling area (Fig. 1) around the PRE in September 2018 because fish resources are flourishing in this season. The fish were immediately identified, weighed, and measured on board after collection, and then stored in aluminum bags at −20 °C for microplastic analysis in the laboratory.

In the laboratory, the GIT and gills were extracted for microplastic inspection. The GIT from esophagus to the intestine near the anus was cut and removed from the bodies of fish (Hermsen et al., 2017). Gill collection was conducted following a detailed description by Collard et al. (2017). In short, gills in both the left and right chambers were cut with scissors and transferred to a clean Petri dish. The first gill arch was selected for morphological examination under a stereomicroscope (Leica M165C, Germany). The length of the gill arch and rakers were measured on the photo by the software Image J (1.46r, National Institutions of Health, USA). Gill arch length was the summation of the lengths of epibranchials, ceratohypobranchials, and hypobranchials. The number of gill rakers (GRs) was counted, and the characteristics of denticles, spacing, and angles were recorded. The filtration area of the gill was calculated using the formula developed by Collard et al. (2017):

$$F = (\sum L - L_{max}) * (\overline{G} - 2x)$$

where $x = L_d * sin\alpha$

where F is the filtration area, L is the GR length, $\overline{G}$ is the mean gap between GRs, α is the angle between the denticle and the blade of the GR, and L_d is the denticle length (Fig. 2). The obtained data are included in Table S1 in the Supplementary Files. A total of 15 out of the 26 fish species excluding the small fish were selected to observe the gill morphologies (Fig. 3).

Tissue digestion, microplastic extraction, observation, and identification were performed based on the protocol described by Li et al. (2018). In brief, the GIT and gills were placed into different clean glass conical flasks. Tissues in each conical flask were digested with 200 mL of 10% KOH solution. The flasks were covered with aluminum foils and incubated for 24–48 h in a thermostatic oscillator at 60 °C to complete the digestion of organic matter. After digestion, the solution was decanted and filtered with a 20 μm membrane filter (Millipore, NY20, USA). The flasks were rinsed with distilled water several times and filtered through the same filter. Meanwhile, a recovery rate test was performed according to the procedures described by Karami et al. (2017) to ensure the validity of the experimental results. Briefly, 2 g muscle samples were separately spiked with 100 red fibers in a conical flask. The mixtures were added to 200 mL of 10% KOH solution and subsequently shaken for 24 h to complete the digestion and incubated overnight at 25 °C. Subsequently, the digestates were filtrated through a 20 μm membrane filter. Red fibers left on the filter were used to calculate the recovery rate.

The collected filters were observed under a stereo light microscope (OLYMPUS SZX10, Tokyo, Japan) and the suspected microplastics were checked and photographed using a digital camera (OLYMPUS DP80, Tokyo, Japan). The particle numbers, shapes (fiber, fragment, film), and colors of suspected microplastics on the filters were identified and recorded. The sizes of microplastics were measured by digital Image J photos and were classified into 0.02–1 mm, 1–2 mm, 2–3 mm, 3–4 mm, and 4–5 mm (Lin et al., 2018).

A total of 104 items (62%) among the suspected microplastics were selected based on their typical appearance and size in the samples. The compositions were identified by micro-FTIR (Nicolet iN 10, Thermo

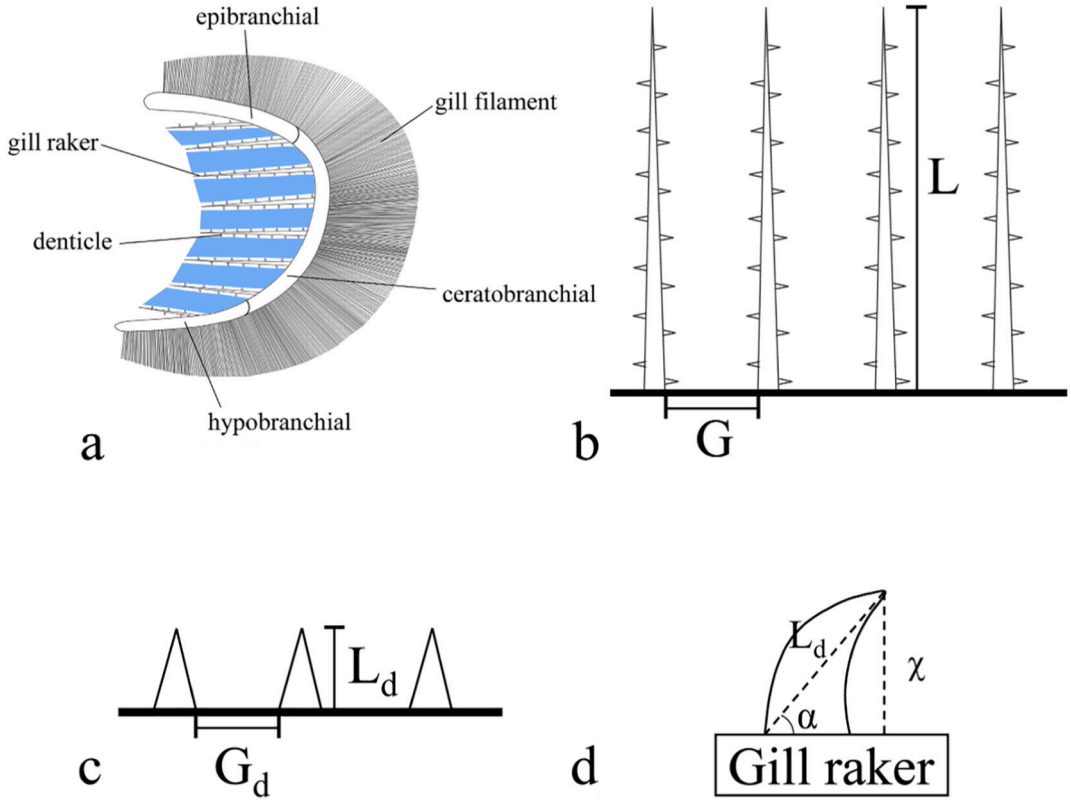

Fig. 2. Schematic diagrams of the structure of gills. (a) The filtration areas (blue part) on the gill. (b) The structure of gill rakers. G: gaps between gill rakers, L: length of gill rakers. (c) The structure of denticles. G_d: gaps between denticles, L_d: length of denticles. (d) α: inclination angle between denticles and gill rakers, χ: length of denticles using α. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Fisher, USA) coupled with an MCT detector. The infrared spectrum in the range of 4000–400 cm^{-1} was collected 16 times on each identified particle. The obtained spectra were compared with the standard FTIR spectrum database using OMNIC software (Version 8.2, Nicolet, USA). The composition of microplastics was matched against a commercial polymer database and confirmed while matching the degree with a standard spectrum > 80% (Cai et al., 2017). All abundances were rectified and recalculated, excluding the non-plastic items.

Cotton lab-coats, nitrile gloves, and masks were worn during the entire fishing collection and laboratory analysis process. A clean Petri dish with a wetted 20 μm membrane filter was used to collect the airborne contamination on board and during each batch of the experiment. All liquids used in the experiment were filtered through a 20 μm membrane filter before use. To minimize airborne contamination, the dissecting tools and glass containers were rinsed three times with distilled water, and immediately covered with aluminum foil before use. Before dissection, the outer surface of the fish was thoroughly rinsed with distilled water to reduce the attached microplastics. Procedural blanks were performed throughout the experiment alongside each batch of samples.

Statistical analysis was performed using SPSS Statistics (version 20.0, IBM, America) at a significance level of 0.05. Normal distribution characteristics and homogeneity of variance of the data were tested prior to further statistical analysis. The differences in microplastic abundances in fish related to different living habitats and feeding habits were examined using the Kruskal-Wallis H method (K-W test). The differences in microplastic abundances within organs were examined by K-W test in the case of heterogeneity of variance. Linear relationships between microplastic abundance and biological parameters of fish, including body size, weight, and gill filtration areas, were analyzed with Pearson's test (Peters and Bratton, 2016).

In the QA/QC procedure, four plastic fibers were collected from the laboratory control batches, while no airborne microplastics were observed during the fish collection process. The four suspected fibers were of the same white color and fabric-like morphological characteristics with a clean surface. These fibers were identified as 100% of the cotton component according to the Micro-FTIR results, which were considered to be released from the lab coat.

A total of 168 microplastics were extracted from 141 out of 337 individuals across all 26 species. The recovery rate was lowest at 95%, indicating that the experimental results were valid (Karami et al., 2017). The occurrence rate of microplastics varied from 15.4% to 80.0% among different fish species. The microplastic abundance ranged from 0.17 items $individual^{-1}$ (*Boleophthalmus pectinirostris* & *Acanthogobius flavimanus*) to 1.33 items $individual^{-1}$ (*Plectorhynchus cinctus*), with an average of 0.57 items $individual^{-1}$ (Fig. 4a). The highest abundance was recorded in the species *Plectorhynchus cinctus*, while the lowest abundance was found in *Acanthogobius flavimanus* and *Boleophthalmus pectinirostris*. A positive relationship was observed between microplastic abundance and body length ($r_{Pearson} = 0.57$, $p < 0.05$) and body weight ($r_{Pearson} = 0.68$, $p < 0.05$). No significant difference was found in microplastic abundance relating to different living habitats (Kruskal-Wallis test, $p > 0.05$) or feeding habits of fish (Kruskal-Wallis test, $p > 0.05$).

Microplastics were detected in the GIT and gills of fish. Microplastic abundance ranged from 0.06 to 0.88 items $individual^{-1}$ in GIT with an average of 0.37 ± 0.24 items $individual^{-1}$; and from 0.06 to 0.79 items $individual^{-1}$ in gills with a mean value of 0.21 ± 0.19 items $individual^{-1}$, showed significant differences in their distributions (Kruskal-Wallis test, $p < 0.01$). The length of the gill arch was positively correlated with the body length of fish ($r_{Pearson} = 0.71$, $p < 0.05$) and the filtration area of gills ($r_{Pearson} = 0.83$, $p < 0.05$), respectively. The largest filtration area was 862.20 mm^2 in *Mugil cephalus*, followed by 26.80 mm^2 in *Pseudosciaena crocea*, while the

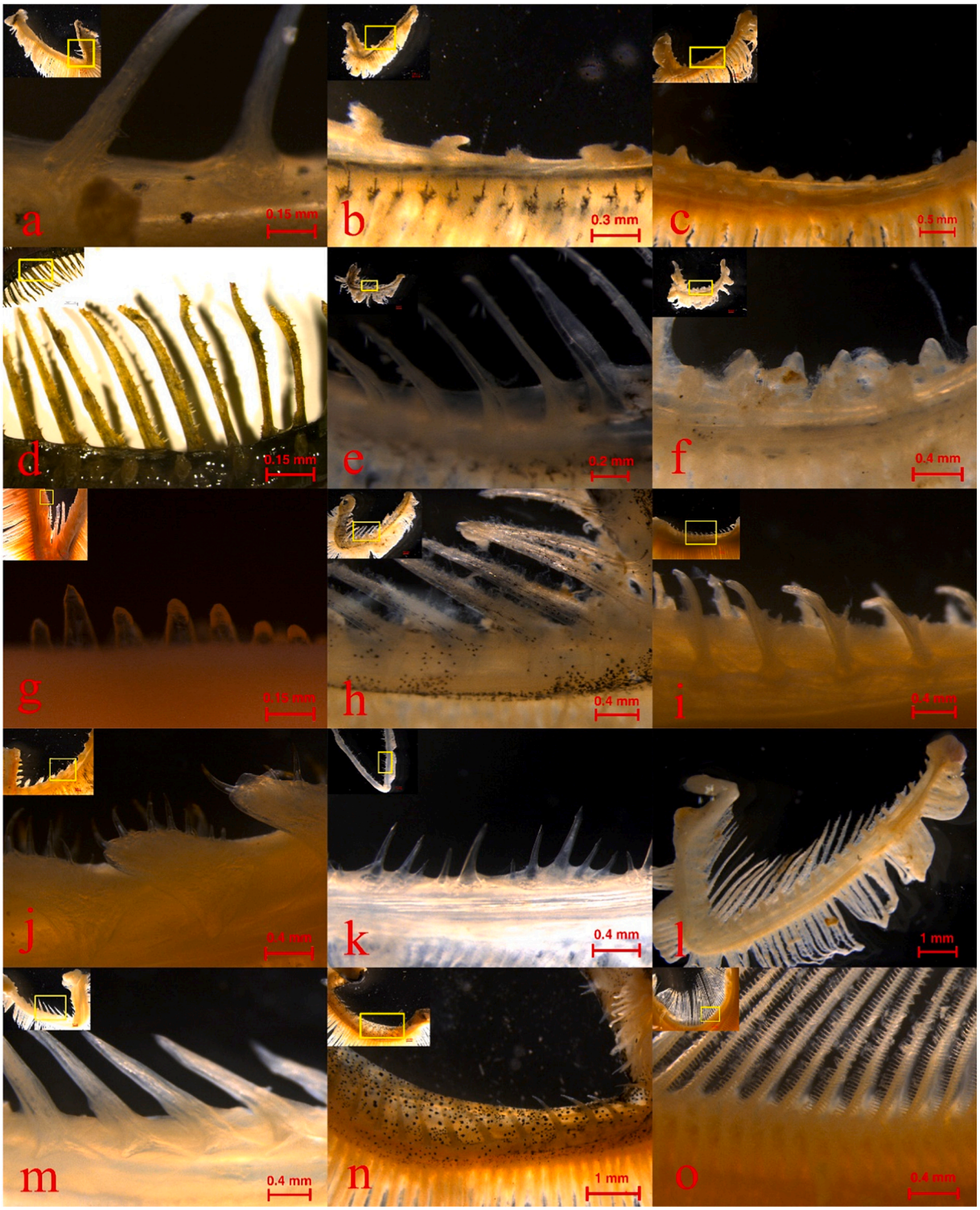

Fig. 3. The morphological characteristics of gill rakers in different species of fish. (a) *Sillago sihama*, (b) *Bostrychus sinensis*, (c) *Taenioides anguillaris*, (d) *Pseudosciaena crocea*, (e) *Glossogobius giuris*, (f) *Acanthogobius flavimanus*, (g) *Platycephalus indicus*, (h) *Johnius belengerii*, (i) *Siganus fuscescens*, (j) *Nemipterus virgatus*, (k) *Harpodon nehereus*, (l) *Collichthys lucidus*, (m) *Branchiostegus japonicas*, (n) *Pampus argenteus*, and (o) *Mugil cephalus*.

smallest was 0.09 mm^2 in *Bostrychus sinensis* (Fig. 3). Microplastic abundance in gill or GIT did not show significant relevance to the filtration area of gills (Pearson test, $p > 0.05$).

Three shapes of microplastics were observed in the bodies of fish, including fiber, fragment, and film. The proportion of fibers (93.45%) was significantly higher than that of fragments (5.95%) and films (0.60%) (Kruskal-Wallis test, $p < 0.01$, Fig. 4c, d). Films were only found in the gills of *Cynoglossus trigrammus*. There were seven colors observed in microplastics from fish, including black (30.36%), blue (20.24%), red (17.26%), yellow (15.48%), white (13.69%), green (2.38%), and purple (0.60%) (Fig. 4e, f). The size of microplastics ranged from 183 μm to 4903 μm. The majority of microplastics were in the size ranges of 0.02–1 mm (34.81%), 1–2 mm (34.81%), and 2–3 mm (20.89%) (Fig. 4g, h).

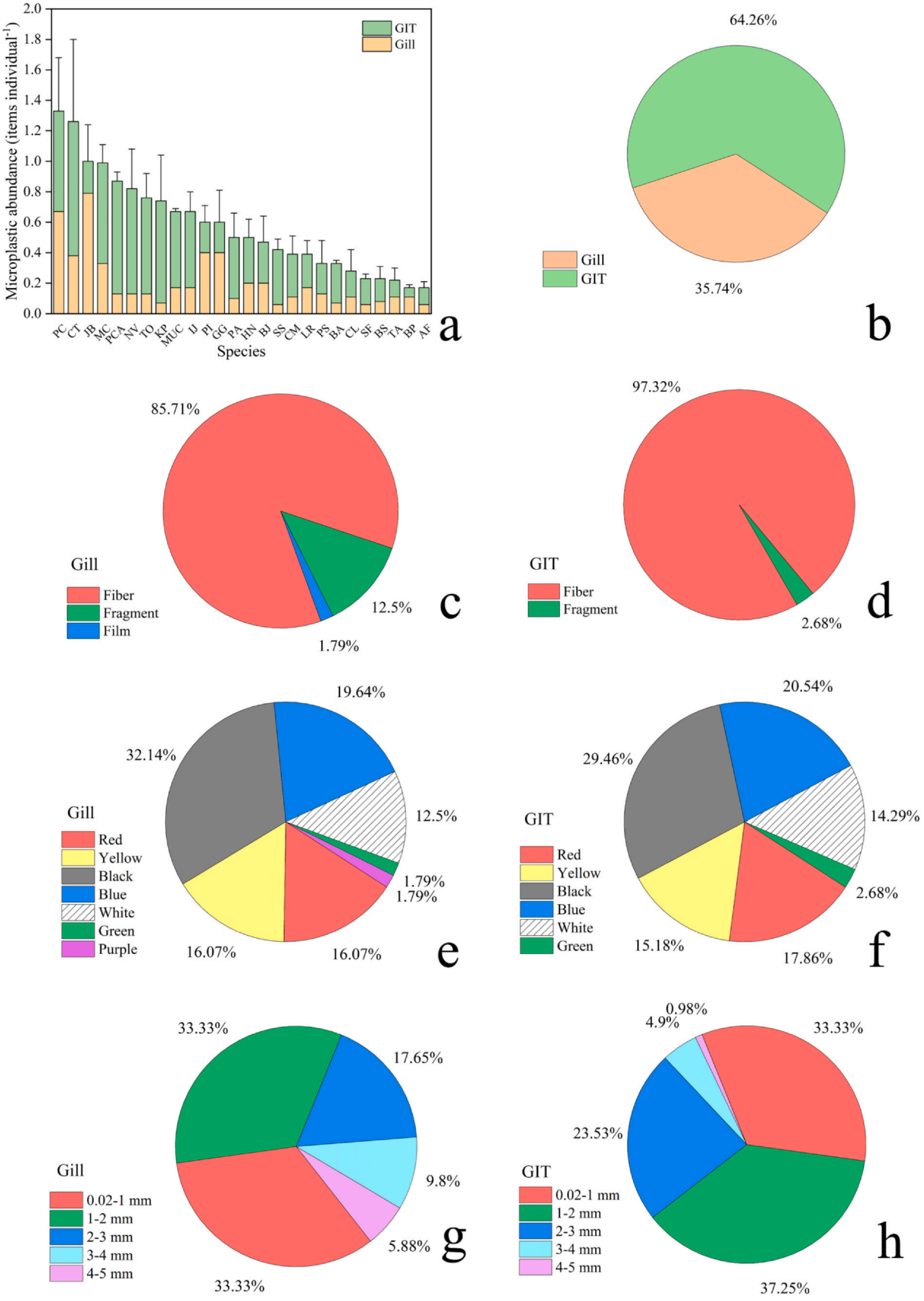

Fig. 4. Microplastic abundances in different species of commercial fish (a); microplastic proportion in Gill and GIT (b); microplastic shapes Gill (c) and GIT (d); microplastic colors in Gill (e) and GIT (f); microplastic sizes in Gill (g) and GIT (h).

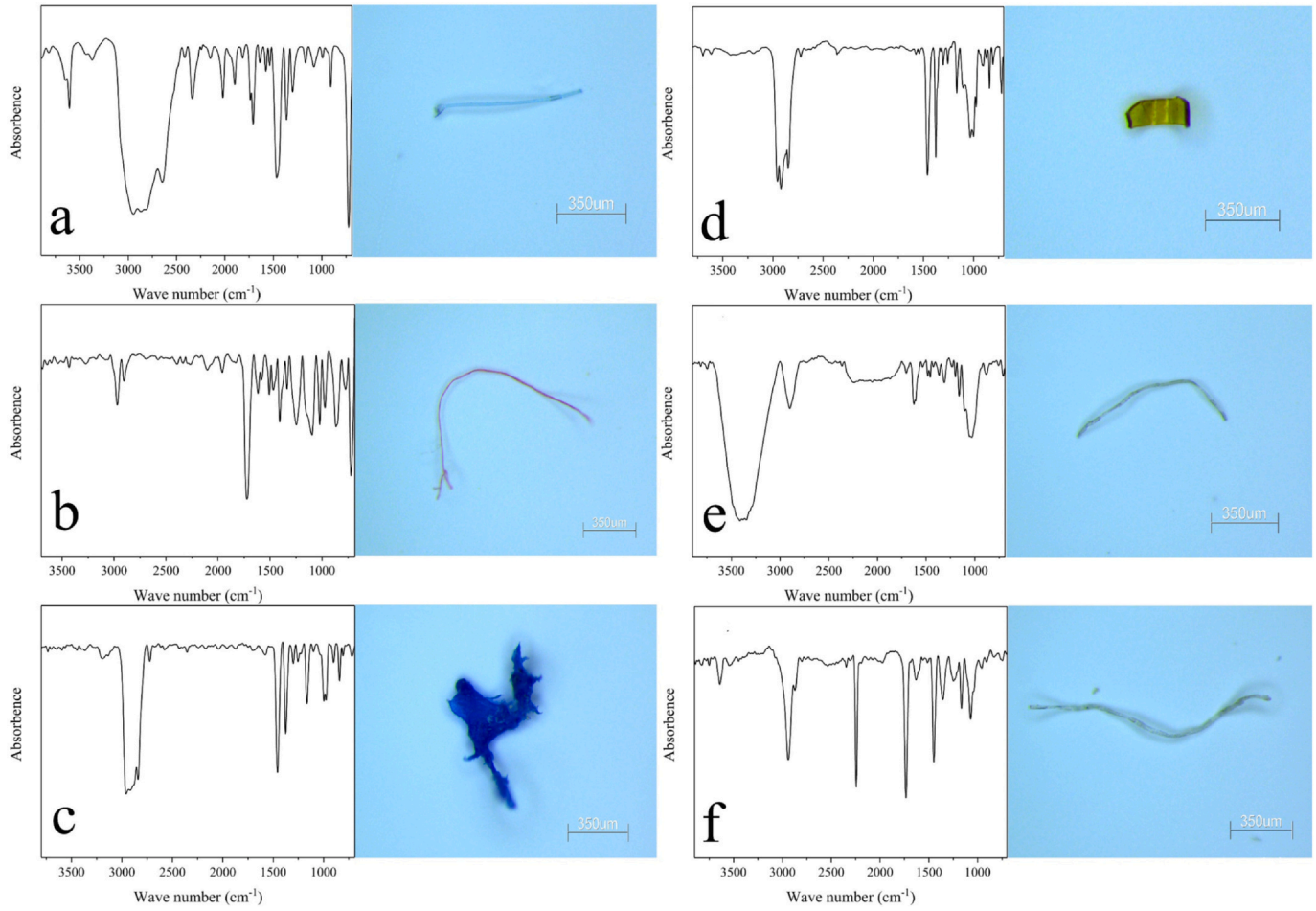

Fig. 5. The infrared spectra of representative microplastics. (a) PE, (b) PET, (c) PP, (d) PP-PE, (e) Cellophane, (f) Poly (acrylonitrile).

The chemical compositions of the microplastics were confirmed by the decreasing abundance sequence as polyethylene terephthalate (PET) (38.2%), polypropylene-polyethylene copolymer (PP-PE) (27.3%), cellophane (25.5%), poly (acrylonitrile) (3.6%), polypropylene (PP) (1.8%), and polyethylene (PE) (1.8%) (Fig. 5).

The abundance of microplastics in this study was relatively low when compared to the previous studies (Table S3), higher abundances were found in the estuarine fish (12.1 items individual^{-1}) from the Bahia Blanca Estuary, Argentina (Arias et al., 2019), and marine fish (8–23 items individual^{-1}) in the Central Adriatic Sea (Renzi et al., 2019). In the Río de la Plata estuary, a large number of microplastics in fish were affected by the sewage discharged from the sampling sites, suggesting the influence of a significant local pollution source on microplastic accumulation in fish (Pazos et al., 2017). In the Persian Gulf, microplastics were detected in all tissues including skin, muscle, gut, gills, and liver of the four examined fish species (*P. indicus*, *Saurida tumbil*, *S. sihama*, and *Cynoglossus abbreviatus*).

In the present study, microplastics were observed in the GIT of all fishes. Ingestion of microplastics might be due to the uptake from surface water, water column, sediments, or from consumption of microplastic-contaminated prey (Jovanović et al., 2018). The retrieval of microplastics was not significantly different between carnivorous and omnivorous fishes or between pelagic and demersal fishes in this study, indicating that the prevalence of microplastics in estuarine environments may lead to wide bioavailability to aquatic organisms in this region. As digestion and degradation of microplastics in fish bodies is very difficult or impossible, continuing microplastic accumulation in the GIT may have a physical or chemical impact on the health of fish (Browne et al., 2008). It has been reported that microplastic ingestion can significantly reduce feeding behavior, block digestive tracts, decrease reproduction, and even enter non-digestion tissues, such as liver tissues (Avio et al., 2015). In a recent study, microplastics < 100 μm were detected in the muscular tissues of commercial fish *Serranus scriba* from Tunisian coasts (Zitouni et al., 2020). In laboratory experiments, microplastics in sizes of hundreds of microns in gut lumen transferred to the liver as well as hepatopancreas by endocytosis, phagocytosis, or other mechanisms (Avio et al., 2015; Brennecke et al., 2015). Even though there is no direct evidence showing that ingestion of microplastics would significantly harm human health, the presence of microplastics in edible parts such as muscular tissues (fish) or hepatopancreas (crab) is a threat to food safety due to the associated contaminants (Fossi et al., 2018). Batel et al. detected benzo[*a*]pyrene (BaP) in the gill filaments of adult zebrafish after 6 and 24 h exposure to PE particles spiked with BaP (Batel et al., 2018). The chemicals released from microplastics may enter the capillary vessel (Barboza et al., 2020) and transfer to the circulatory system (Wang et al., 2015). Additionally, microplastics play a role as accelerators in bioaccumulating toxicants. Zhu et al. (2020) found that microplastics may accelerate the precipitation of trace metals in oysters and exceed food safety levels by ten times. Therefore, microplastic contamination in fish should be monitored to evaluate the effects of environmental pollution on human food safety.

In this study, microplastic abundance in the gill comprised 35.74% of the total, indicating that the gill plays an important role in microplastic accumulation. To date, few studies have revealed the presence of microplastics in fish gills. As reported by Abbasi et al. (2018), microplastic abundance was significantly higher in fish gills than in guts. Gills consist of gill slits, arch, and rakers (Dorit et al., 1991), which play an

important role in respiratory gas exchange and particle filtration for food (Salman et al., 2005). GRs usually filter large particles and plankton from water current and divert them into the esophagus; thus, microplastics may also be retained during the filtration and feeding procedures. Large filtration areas and small gaps between GRs were considered the main factors in trapping plastic particles and solid items in the gills (Collard et al., 2017). In addition, denticles (Rykacaewski, 2009) and mucus (Alsafy, 2013) can help to reduce the mesh size of the branchial sieve to enhance the planktivory ability of microplastics. In the present study, we found that the largest filtration area of gill was in *Muraenesox cinnaeus*, and the highest abundance of microplastics was in *Johnius belengerii*. This indicated that the morphological characteristics of GRs were not the only factor attributing to microplastic accumulation in the gill. The habitats that fish live in may also play an important role in microplastic contamination (Davison and Asch, 2011). An increase in the environmental availability of microplastics could subsequently enhance the risk of microplastic ingestion and the related adverse biological consequences (Browne et al., 2010). In the laboratory, fish gills have been documented as the main organ exposed to microplastics, and high concentrations could cause phytotoxicity and pathological changes in gill tissues (Ding et al., 2018). Low-density polyethylene (LDPE) causes basal cell hyperplasia, secondary lamellae distortion, epithelial sloughing, and desquamation in the gill tissues of African catfish (Karami et al., 2016). Microplastics stuck in the gills have the potential to trigger physical damage, such as breakage of filaments, facilitating the entry of microplastics and increasing the probability of infections (Jabeen et al., 2018). In addition, fish contaminated by microplastics in the North-East Atlantic Ocean had significantly higher lipid peroxidation levels in the gills than fish without microplastics (Barboza et al., 2020), while gill lipid peroxidation may compromise respiration and biotransformation of xenobiotics among other crucial processes (Pandey et al., 2008). Thus, neglecting microplastic accumulation in gills will underestimate the associated biological risks to aquatic organisms, for example, pollutant migration from microplastics to the tissues (Monteiro et al., 2018) and trophic transfer to the food webs (Diepens and Koelmans, 2018). Therefore, the gills should be considered an essential organ for microplastics in fish in future studies.

Our results showed that more than 90% of microplastics were < 3 mm in size. This is consistent with previous studies showing that most of the plastic items observed in the GIT of fishes were microplastics (Pazos et al., 2017). Large plastic debris was inclined to be ingested by bigger organisms; for instance, a 207 mm of suspected broken and eroded plastic was observed in the stomachs of *Scyliorhinus canicular* (Smith, 2018). The sizes of microplastics are similar to those of natural foods and likely to be intentionally or accidently ingested by fish during the foraging process (Ory et al., 2017).

The morphological characteristics of microplastics may play an important role in their retention and excretion in the GIT of fishes. Fibers are one-dimensional materials and can be easily deformed to smaller sizes when compared with hard fragments and pellets. Moreover, fibers are more flexible to enter the slender alimentary canals, and ingested synthetic fibers can get tangled and form agglomerates that potentially block the GIT, resulting in the accumulation of plastic fibers in fishes (Neves et al., 2015). Different shapes of plastic items have been proven to go through a complete ingestion-egestion process in the body of fish (Ory et al., 2018). As microplastics experienced a complete digestive transit circulation, microplastics could have been egested after an ephemeral dwelling in the GIT; thus, the presence of microplastics in GIT was more likely to indicate that the fish had ingested plastic items recently (Güven et al., 2017).

Black, blue, and red microplastics were the dominant types in the fish samples, whereas transparent microplastics were not detected in this study. Compared to transparent particles, colorful plastics are more recognizable by foraging fish (Land and Osorio, 2011). In the River Thames (McGoran et al., 2017), black fibers were observed in the alimentary canals of European smelt fishes. Black microplastics were also prevalent in the GIT of fish from the Musa Estuary (Abbasi et al., 2018) and Clyde Estuary (Murphy et al., 2017). The poor visibility in the deep ocean weakens the recognition capability of fish regarding microplastics in light color, which misleads fish to ingest microplastics without distinction (Katsnelson, 2015). Ory et al. (2017) found that *Decapterus muroadsi* dwelling on the coast of Rapa Nui was apt to ingest blue polyethylene fragments due to their similar appearance to blue copepod species, a food source consumed by the same fish species. In addition, recent studies have reported that blue microplastics or plastic debris are the dominant type and account for > 30% of the samples (Güven et al., 2017). A similar appearance to red algae and invertebrate species made red fibers massively accumulated in fish *Girella laevifrons* (Mizraji et al., 2017). Light attenuation in deep water may result in the preferential ingestion of blue-colored plastics (Land and Osorio, 2011). In fact, high-energy blue wavelength of light between 400 and 440 nm exhibited the strongest penetration ability among visible lights, while the inability of low-energy wavelength of light e.g., red light, to penetrate deep water rendered the observation of red-colored microplastics by fishes from above (Crawford and Quinn, 2017). When there was a shortage of food supply, those visible and disguised prey were more prone to be mistaken as potential food sources. Therefore, color may play an important role in microplastic ingestion by aquatic organisms. However, this assumption should be tested by simultaneous investigation of microplastic contamination in aquatic organisms.

According to micro-FTIR analysis, the main types of polymers found in the fish from PRE were PET, PP, PE, and cellophane. The results were similar to the polymer types in the fish from the Mondego Estuary (Bessa et al., 2018) and fish collected along the Spanish Mediterranean coast (Compa et al., 2018). PET, widely used in textile and fishing gears (Alomar et al., 2017), is the most common type detected in our fish samples. Wastewater treatment plant (WWTP) effluent is usually considered as an important point source of microplastics in the riverine environment (Ziajahromi et al., 2017). Large amounts of anthropogenic fibers enter the WWTP from domestic laundry sewage and are finally discharged into rivers (Welden and Cowie, 2017). Approximately 700,000 fibers were estimated to be generated from a 6 kg laundry washing (Napper and Thompson, 2016). Another source of PET was the fragmentation of derelict fishing gears (e.g., ropes and nets). It was found that 640,000 tons of fishing gear were lost every year. The fishing gear consisting of polyethylene, polypropylene, and nylon, could release microplastics to the benthic environment at a mass loss rate of 3968 tons per month (Welden and Cowie, 2017). Cellophane is a synthesized material that is used in tobacco and wrappers, accounting for a quarter of the whole polymer in wild fish from the PRE. The appearance of this polymer resulted from the weathering of plastic debris, especially in areas lacking proper waste collection (Castillo et al., 2016). Therefore, a wider variety of pollution sources of microplastics were found in the bodies of estuarine fish, which may have contributed to the intense anthropogenic activity and high population densities along the urban estuary.

Microplastic contaminants in wild fish collected from the PRE were investigated. The prevalence of microplastics in all fish species might be a result of widespread microplastic distribution in water and sediments of the Pearl River basin. Although the level of microplastic abundance was relatively low in the estuarine fish, microplastics could be frequently detected in gills and gastrointestinal tracts. Microplastic contamination was positively related to the body size of fish, but had no relationship with the feeding and living habitats of fish. A great majority of microplastics (64.26%) were found in the GIT and the rest (35.74%) were found in the gills. Both the gill and the GIT play an important role in microplastic accumulation, and the neglect of gill parts in previous studies might underestimate the amounts of microplastics in fish. Further investigation is required to determine whether fish exhibit preferential foraging behaviors for microplastics with special characteristics such as certain color, shape, or polymer

composition.

CRediT authorship contribution statement

Lang Lin: Methodology, Formal analysis, Writing-original draft. Li-Sha Ma: Methodology, Formal analysis, Resources. Heng-Xiang Li: Conceptualization, Methodology, Writing-review & editing. Yun-Feng Pan: Formal analysis, Writing-review & editing. Shan Liu: Writing-review & editing. Li Zhang: software & editing. Jin-Ping Peng: μ-FTIR analysis, Data analysis. Lincoln Fok: Writing review & editing, Picture. Xiang-Rong Xu: Conceptualization, Writing review & editing. Wei-Hong He: Resource, Writing review & editing.

Declaration of competing interest

The authors declare that they have no known conflict of interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This study was supported by the National Key Research and Development Program (2017YFB0903703), the Natural Science Foundation of Guangdong Province (2018A030313136), the National Natural Science Foundation of China (1876129), the Hong Kong SAR Government, Research Grant Council (18300618), Innovation Academy of South China Sea Ecology and Environmental Engineering, Chinese Academy of Sciences (ISEE2019ZR03, ISEE2018PY03, ISEE2018ZD02), Key Special Project for Introduced Talents Team of Southern Marine Science and Engineering, Guangdong Laboratory (Guangzhou) (GML2019ZD0404) and the Science and Technology Planning Project of Guangdong Province (2017B030314052). We are deeply indebted to those anonymous reviewers for their valuable comments and suggestion.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.marpolbul.2020.111650.

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